Cambridge Technicals
Engineering

Unit 23: Applied mathematics for engineering

Level 3 Cambridge Technical Certificate/Diploma in Engineering
05823 - 05825 & 05873

Mark Scheme for January 2023

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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MARKING INSTRUCTIONS

PREPARATION FOR MARKING

RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone or the RM Assessor messaging system, or by email.

5. **Crossed Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

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Multiple Choice Question Responses
When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses
When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. (The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)

Short Answer Questions (requiring a more developed response, worth **two or more marks**)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional lined pages if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add an annotation to confirm that the work has been seen.

7. Award No Response (NR) if:
   - there is nothing written in the answer space

   Award Zero '0' if:
   - anything is written in the answer space and is not worthy of credit (this includes text and symbols).

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Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The RM Assessor **comments box** is used by your team leader to explain the marking of the practice responses.
Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
If you have any questions or comments for your team leader, use the phone, the RM Assessor messaging system, or e-mail.

9. Assistant Examiners will email a brief report on the performance of candidates to your Team Leader (Supervisor) by the end of the marking period. Your report should contain notes on particular strength displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

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10. **Annotations (updated for RM assessor marking)**

Marking annotations in RM Assessor

Annotation	Meaning
	Correct response
	Incorrect response
	Missing something
	Follow through
	Benefit of doubt
	Ignore subsequent working
	Method mark awarded 0
	Method mark awarded 1
	Accuracy mark awarded 0
	Accuracy mark awarded 1
	Independent mark awarded 0
	Independent mark awarded 1
	Special Case
	Misread

Mark scheme abbreviations

Other abbreviations in mark scheme	Meaning
oe	Or equivalent
Soi	Seen or implied
www	Without wrong working
ecf	Error carried forward
DM	Method mark dependent on previous M mark

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11. **Subject specific marking instructions**

Annotations should be used whenever appropriate during your marking.

The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded. These annotations must be in the body of the work and **not** anywhere near the right-hand margin of each page.

Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct *solutions* leading to correct answers are awarded full marks but work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly.

Correct but unfamiliar or unexpected methods are often signalled by a correct result following an *apparently* incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) you should contact your Team Leader.

The following types of marks are available.

M
A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

DM
A method mark which is dependent on a previous method mark.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

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B

Mark for a correct result or statement independent of Method marks.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

When a part of a question has two or more 'method' steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

The abbreviation ft implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only — differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise. Candidates are expected to give numerical answers to an appropriate degree of accuracy, with 3 significant figures often being the norm. Small variations in the degree of accuracy to which an answer is given (e.g. 2 or 4 significant figures where 3 is expected) should not normally be penalised, while answers which are grossly over- or under-specified should normally result in the loss of a mark. The situation regarding any particular cases where the accuracy of the answer may be a marking issue should be detailed in the mark scheme rationale. If in doubt, contact your Team Leader.

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Question			Answer	Marks	Guidance
1	(i)		$160^2 - 4(40^2 - \frac{\pi 40^2}{4})$ OR $4\times(80\times40) + 80\times80 + 4\times(\pi\times40^2)/4$	M1	At least 2 of the 3 composite areas attempted (from centre/4corners/4edges) using appropriate formulas. May be embedded in volume calculations
			Area of top of pan = 160^2 – area corners removed OR sum of 9 areas	M1	All areas considered using appropriate formulas
			$=24226.55$ mm^2	A1	Note: exact equivalent = $19200 + 1600\pi$
			Volume = $24226.55\times60 = 1453593$ mm^3 ≈ 1.45 (L)	A1	Final answer must be in litres and round to 1.45
				4	
1	(ii)		$(A =)\ 2000000 \div 50 = 40000$	B1	B1 for area of $40000mm^2$oe soi
			$(100 \times 100) + 4(100 \times r) + 4\left(\frac{\pi r^2}{4}\right)$	M1*	Attempt sum of 3 relevant areas (which may be embedded in volume calculations)
			$100^2 + 400r + \pi r^2 = 40000$	A1	Correct equation
			$\pi r^2 + 400r - 30000 = 0$		
			$r = \frac{-400+\sqrt{400^2-4\pi(-30000)}}{2\pi}$	DM1	Solve their 3term quadratic Their use of formula must be correct if seen, can be implied by correct answer to their quadratic
			$= 52.96..$ (mm)	A1	Anything which rounds to 53.0 and -180 must be rejected if seen
				5	
				9	

Question			Answer	Marks	Guidance
2	(i)		$sin\,\alpha = \frac{0.5}{2}$ $\alpha = 14.5^{(o)}$	M1 A1	Implied by $\alpha = \sin^{-1}\frac{(0.5)}{2}$
				2	
2	(ii)		$x^2 + 0.5^2 = 2^2$ $\boldsymbol{x} = \sqrt{2^2 - 0.5^2} = 1.94$ (m)	M1 A1	OR $x = 2\cos(14.5)$ OR $x = 0.5/\tan(14.5)$ Accept 1.9 or better
				2	
2	(iii)		$\tan\theta = \frac{3+y}{4-x}$ $x = 2\cos\alpha$ $y = 2\sin\alpha$ $\tan\theta = \frac{3+2\sin\alpha}{4-2\cos\alpha}$ AG	M1 B1 B1 A1	
				4	
2	(iv)		When $y = 0$, $x = 2$ (and $\alpha = 0$) $\tan\theta = \frac{3+0}{4-2} = \frac{3}{2}$ O: $10g = T\sin\theta$ C: mg = T $10g = mg\sin 56.3$ $m = \frac{10}{\sin 56.3} = 12.0$ (kg) OR $\frac{10\sqrt{13}}{3}$	B1 B1 M1 A1	 Note: $\theta = \tan^{-1}1.5$ $\theta = 56.3^{o}$ Resolve vertical forces for both objects O: may include expression for 2nd string ($T'\sin\alpha$) Solve to obtain correct answer
				4	
				12	

Question			Answer	Marks	Guidance
3	(i)		$Q = \frac{0.4}{0.1}(24-12)$ $= 48$ (W m^{-2})	M1 A1	
				2	
	(ii)		$80 = \frac{0.4}{0.1}(D)$ $(D =)20$ $(T_1 = 20 + 10) = 30$ (°C)	M1 A1 A1	Attempt temp difference by substitution for Q, K, s Correct temp difference soi, does not need to be labelled as D, and may be seen as $T_1 - 10$, but not $10 - T_1$ Allow without label or with wrong label
				3	
3	(iii)	(A)	Wall 1 $\frac{0.1}{K_B} + \frac{0.05}{K_F} + \frac{0.1}{0.4}$ $10 = \frac{20}{\frac{0.1}{K_B} + \frac{0.05}{K_F} + \frac{0.1}{0.4}} \rightarrow \frac{0.1}{K_B} + \frac{0.05}{K_F} + 0.25 = 2$ $\frac{0.1}{K_B} + \frac{0.05}{K_F} = 1.75$ AG	B1* DB1	Correct summation of $\frac{s}{K}$ for the 3 materials Convincing completion
				2	
3	(iii)	(B)	Wall 2 $\frac{0.12}{K_B} + \frac{0.03}{K_F} + \frac{0.1}{0.4}$ $12.5 = \frac{20}{\frac{0.12}{K_B} + \frac{0.03}{K_F} + \frac{0.1}{0.4}} \rightarrow \frac{0.12}{K_B} + \frac{0.03}{K_F} + 0.25 = \frac{20}{12.5}$ $\frac{0.12}{K_B} + \frac{0.03}{K_F} = 1.35$ AG	B1* DB1	Correct summation of $\frac{s}{K}$ for the 3 materials Convincing completion
				2	

Question			Answer	Marks	Guidance
3	(iii)	(C)			Allow any appropriate method to solve equations simultaneously
			$0.1\left(\frac{1}{K_B}\right)+0.05\left(\frac{1}{K_F}\right)=1.75 \quad \rightarrow 10X+5Y=175$ $0.12\left(\frac{1}{K_B}\right)+0.03\left(\frac{1}{K_F}\right)=1.35 \quad \rightarrow 12X+3Y=135$	**M1**	Prepare equations for elimination or substitution process using K_B, K_F or $\frac{1}{K_B}, \frac{1}{K_F}$ eg $\left(\frac{0.1}{K_B}+\frac{0.05}{K_F}\right)\times 0.03 = 1.75\times 0.03$ $\left(\frac{0.12}{K_B}+\frac{0.03}{K_F}\right)\times 0.05 = 1.35\times 0.05$
				M1	Eliminate or substitute to obtain equation in one variable only
			$12\left(\frac{175-5Y}{10}\right)+3Y = 135$	**A1**	Any correct equation in one variable only eg $\frac{0.006}{K_B}-\frac{0.003}{K_B}=1.35\times 0.05-1.75\times 0.03$
			$(Y=)\ \frac{1}{K_F}=25 \quad \rightarrow \quad (X=)\ \frac{1}{K_B}=5$	**A1**	One value correct for K_B, K_F or $\frac{1}{K_B}, \frac{1}{K_F}$
			$K_F=0.04,\ K_B=0.2$	**A1**	Both values correct for K_B, K_F Accept correct answers from efficient use of calculator
				5	
				14	

Question			Answer	Marks	Guidance
4	(i)			**B1** **B1** **B1** **B1**	Appropriate scales on both axes starting at (0,0) with labels t and v or time and velocity/speed on horizontal and vertical axes respectively Ends at (30, 17.9..) Peaks at (10, 44.1..) Smooth continuous curve Can only be awarded if all previous marks awarded
				4	
4	(ii)		Distance = $\int_0^{30} 12te^{-\frac{t}{10}}dt$ =		
			$\int u\frac{dv}{dt} = uv - \int v\frac{du}{dt}$		
			$u = 12t \quad \frac{du}{dt} = 12 \qquad \frac{dv}{dt} = e^{-\frac{t}{10}} \quad v = Ae^{-\frac{t}{10}}$	**M1***	Evidence of attempt at integration by parts, with $A = \pm 10$ or $\pm\frac{1}{10}$
			$= 12t\left(-10e^{-\frac{t}{10}}\right)$	**DM1**	Correct form using their u, v
			$-\int\left(-10e^{-\frac{t}{10}}\right)(12)dt$	**DM1**	Correct form using their $v, \frac{du}{dt}$
			$\left[-120te^{-\frac{t}{10}} - 1200\,e^{-\frac{t}{10}}\right]_0^{30}$	**A1**	Integration complete and correct Limits not required yet
			$= (-120(30)e^{-3} - 1200e^{-3}) - (0 - 1200)$	**M1**	Apply limits in correct order throughout
			$= 1200(1 - 4e^{-3})$ **AG**	**A1**	Must be convincing
				6	
				10	

Question			Answer	Marks	Guidance
5	(i)		$\overrightarrow{OA} = (2i + 4j + 5k)$ $\overrightarrow{OB} = (3i + 2j + 1k)$	B1	CAO
				1	
5	(ii)		$\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 2 & 4 & 5 \\ 3 & 2 & 1 \end{vmatrix}$	M1	Correct method for cross product, evidenced by one element formed correctly
			$\overrightarrow{OA} \times \overrightarrow{OB} = ((4-10)i - (2-15)j + (4-12)k)$	A1	All 3 elements correct but unsimplified
			$(-6\mathbf{i} + 13\mathbf{j} - 8\mathbf{k})$	A1	CAO
				3	
5	(iii)		$\lvert -6i + 13j - 8k \rvert = \sqrt{36 + 169 + 64} \quad (= \sqrt{269})$	M1	Magnitude of their vector from 5ii
			Area = $\frac{\sqrt{269}}{2} = 8.2$	A1	Exact value or decimal correct to 1dp
				2	
5	(iv)		$\lvert\overrightarrow{OA}\rvert = \sqrt{2^2 + 4^2 + 5^2} \quad = (\sqrt{45})$ $\lvert\overrightarrow{OB}\rvert = \sqrt{3^2 + 2^2 + 1^2} \quad = (\sqrt{14})$	M1	Magnitudes of their $\overrightarrow{OA}$ and $\overrightarrow{OB}$
			Using vector product $\lvert\overrightarrow{OA}\rvert\lvert\overrightarrow{OB}\rvert \sin(\text{AOB}) = \lvert\overrightarrow{OA} \times \overrightarrow{OB}\rvert$		
			$\sqrt{45} \times \sqrt{14} \sin(\text{AOB}) = \sqrt{269}$	M1 A1	Any valid method, eg solution of triangle using $Area = \frac{1}{2}ab\sin C \rightarrow 8.2 = \frac{1}{2}\sqrt{45}\sqrt{14}\sin(AOB)$
			sin(AOB) = 0.6534		
			AOB = 40.8°	A1	
				4	
				10	

Question			Answer	Marks	Guidance
6	(i)		$5 = \frac{325}{\sqrt{32.5^2+(2\pi.50L)^2}}$	B1	Substitution of $V = 325, I = 5, f = 50, R = 32.5$ into correct formula correctly
			$32.5^2 + (100\pi L)^2 = \left(\frac{325}{5}\right)^2$	M1	Attempt rearrangement and deal with the square root by squaring both sides
			$(100\pi L)^2 = 65^2 - 32.5^2 \quad (= 4225 - 1056.25)$		
			$L^2 = \frac{3168.75}{(100\pi L)^2}$		
			L= 0.179	A1	0.18 or better
				3	
6	(ii)		$(\theta) = \tan^{-1}\frac{2\pi.50(0.179..)}{32.5} \quad (= \tan^{-1}(1.732..))$	M1	Correct unsimplified expression for inverse tan using their value for L
			$\theta = \frac{\pi}{3}$	A1	Accept 1.05 or better
				2	
6	(iii)		$(vi) = V\sin(2\pi ft) \times \mathrm{I}\sin(2\pi ft + \theta)$	B1	Forms vi correctly, must be seen
			$= \frac{VI}{2}\{\cos(2\pi ft - (2\pi ft + \theta)) - \cos(2\pi ft + 2\pi ft + \theta)\}$	M1	Using $\sin A \sin B = \frac{1}{2}\{\cos(A-B) - \cos(A+B)\}$
			$= \frac{VI}{2}\{\cos(-\theta) - \cos(4\pi ft + \theta)\}$ and sight of $\cos(-\theta) = \cos(\theta)$		
			$vi = \frac{VI}{2}(\cos\theta - \cos(4\pi ft + \theta))$ AG	A1	Note: reversing to $\sin(2\pi ft + \theta) \times \sin(2\pi ft)$ gives $(\cos\theta - \cos(4\pi ft + \theta))$ directly
				3	

Question			Answer	Marks	Guidance
6	(iv)		$(P) = \frac{1}{0.02}\int_0^{0.02}\left(\frac{325\times5}{2}\right)(\cos\theta - \cos(4\pi ft+\theta))\,\mathrm{d}t$	M1	Attempts to set up $\int vi$ with substitution of T, V, I seen here or later
			$= 40625\left[t\cos\theta - \frac{\sin(4\pi ft+\theta)}{4\pi f}\right]_0^{0.02}$	M1	Either term integrated correctly
				A1	Both terms correctly integrated
			$= 40625\left[\left(0.02\cos\frac{\pi}{3} - \frac{\sin(4\pi+\frac{\pi}{3})}{4\pi f}\right) - \left(0 - \frac{\sin\frac{\pi}{3}}{4\pi f}\right)\right]$		
			$= 40625\left(0.02\cos\frac{\pi}{3}\right)$		
			P = 406.25 (W)	A1	
				4	
				12	

Question			Answer	Marks	Guidance
7	(i)		$\frac{dh}{dt} = -0.1h$ $\int \frac{dh}{h} = \int -0.1 dt$ $\ln h = -0.1t \ (+K)$ $h = e^{-0.1t+K} \quad (= D\,e^{-0.1t})$ $t = 0, h = 0.75 \Rightarrow D = 0.75$ $h = 0.75e^{-0.1t}$	**B1** **M1** **M1** **M1** **A1**	Variables separated correctly ready for integration Integrate to obtain correct form Change to exponential form K now present Apply conditions Accept $h = e^{-0.1t+\ln 0.75}$
				5	
7	(ii)		$0.3 = 0.75e^{-0.1t}$ $\frac{0.3}{0.75} = e^{-0.1t}$ $\ln \frac{0.3}{0.75} = -0.1t$ $t = -10\ln(0.4)$ $= 9.16$ (s)	**M1** **M1** **A1**	Make the exponential term the subject of equation using their h from 7i Take logs
				3	

Question			Answer	Marks	Guidance
7	(iii)		$s = 1.5(e^{-0.05t} - e^{-0.1t})$ $\frac{ds}{dt} = 1.5(-0.05e^{-0.05t} + 0.1e^{-0.1t})$	B1	One of the two terms must be correct
			$1.5(-0.05e^{-0.05t} + 0.1e^{-0.1t}) = 0$ $0.1e^{-0.1t} = 0.05e^{-0.05t}$ $e^{-0.1t}e^{0.05t} = 0.5$ $-0.05t = \ln 0.5$	M1	Set their derivative to zero, and take logs at the appropriate point to remove exponential terms
			$t = \frac{1}{-0.05} ln\, 0.5 \quad (= 13.8629\text{ s})$	A1	
			$s = 1.5\left(e^{\ln 0.5} - e^{2\ln 0.5}\right)$ $= 0.375 \quad (m)$	M1 A1	Substitute their t to obtain expression for s
				5	
				13	

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